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RB No. 3H23

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

August 1943 as
Restricted Bulletin 3H23

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESTRICTED BULLETIN

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THE EFFECT OF ARTIFICIAL AGING ON THE TENSILE PROPERTIES OF ALCLAD 24S-T AND 24S-T ALUMINUM ALLOY

By Joseph N. Kotanchik, Walter Woods, and George W. Zender

SUMMARY

An experimental study was made to determine the effect of artificial aging on the tensile properties of alclad 24S-T and 24S-T aluminum-alloy sheet material. The results of the tests show that certain combinations of aging time and temperature cause a marked increase in the yield strength and a small increase in the ultimate strength; these increases are accompanied by a very large decrease in elongation.

A curve is presented that shows the maximum yield strengths that can be obtained by aging this material at various combinations of time and temperature. The higher values of yield stress are obtained in material aged at relatively longer times and lower temperatures.

INTRODUCTION

In the design of an airplane, weight control is a leading problem. Every part of the airplane must be so designed or selected as to eliminate unnecessary weight. One of the most important items that contribute to the gross weight of the airplane is the structure. For this reason, the airplane structure is examined most critically for elimination of unnecessary weight. The continuing advances in methods of analysis are an important factor for bringing about a reduction in weight of the airplane, but the airplane designer and builder must, in addition, utilize other methods for combating the trend toward increased structural weight. One of the most direct methods is to improve the strength properties of materials already available or in current production. This method has the very important advantage that it can be put into use with a minimum of delay and interruption to established methods of production.

A number of aircraft companies are now considering the use of 24S-T aluminum alloy of which the strength properties have been improved by artificial aging. This report presents the results of tensile tests on alclad 24S-T and 24S-T aluminum-alloy sheet material that has been artificially aged at various combinations of temperature and time.

MATERIAL FOR ARTIFICIALLY AGED TEST SPECIMENS

As the purpose of these tests is to present the results that can be obtained by artificial aging of commercially obtainable material, specimens, of the dimensions shown in figure 1, were cut from sheets selected from alclad 24S-T and 24S-T aluminum alloy as received from the manufacturer. The stretching and rolling operations performed on aluminum alloy at the mills are approximately equivalent to the cold work done in giving the sheet a permanent elongation of 1 percent (reference 1). The extent to which the strength properties of 24S-T aluminum alloy can be improved by artificial aging is dependent upon the amount of cold work performed on the material prior to the aging process (reference 1). It is therefore necessary that the material be of uniform quality as regards the amount of cold work performed prior to aging in order that consistent results be obtained from the artificial aging.

For the tests reported herein, the cutting of the 24S-T and the alclad 24S-T specimens from single sheets of each material assured uniformity of the specimens as regards the degree of cold work performed upon them. That the material was uniform as regards cold work is indicated by the consistent trends established by the test data in figures 2 and 3. The extensive adoption of the artificial aging process would necessitate that close regulation be maintained on the uniformity of and the amount of cold work performed on the aluminum alloy.

TEST SPECIMENS

The test specimens were stamped from single sheets of 0.064-inch alclad 24S-T and 24S-T aluminum alloy by means of a die. In the test portion of the specimen, the sheared edges were carefully hand filed to remove the slightly turned edge left by the stamping die. One specimen was made for each combination of time and temperature investigated.

Artificial aging of the specimens was performed in an electrically heated air furnace, and the specimens were cooled in air at room temperature. The test specimens were placed in the furnace, which was at the desired temperature, and the aging time was taken as the entire

period during which each specimen was in the furnace. The results are therefore representative of the values obtained with material that is artificially aged in the same manner.

The data for the tensile stress-strain curve were obtained for each specimen to a value of strain beyond that at the 0.2-percent-offset yield strength. Strains were measured by two Tuckerman optical strain gages of 2-inch gage length attached to opposite sides of the test specimen. The elongation at failure was determined by measuring, after failure, the increase in length of the initial 2-inch gage length of the test specimen to the nearest 0.01 inch.

TEST RESULTS AND DISCUSSION

The results of the tensile tests on the artificially aged test specimens are given in figures 2 to 5.

Figure 2 shows the variation in the ultimate strength, the yield strength, and the elongation of alclad 24S-T material that is subjected to artificial aging for periods of 2, 4, 6, 7, and 10 hours at temperatures that vary from 100° to 500° F. The important information contained in this figure is that a substantial increase in yield strength and decrease in elongation occur in the material when aged in the temperature range of 340° to 400° F. In this temperature range, a small increase in the ultimate strength of the material also occurs.

The most desirable result obtained from artificial aging is the large increase in yield strength. Although this report presents only the results of tensile tests, some compression tests have been performed on artificially aged material and these tests indicated that the compressive yield strength was increased in essentially the same way as the tensile yield strength. By taking into account the increase in yield strength, the airplane designer can effect substantial reductions of weight in certain parts of the airplane. For example, the full increase in yield strength can be utilized in the design of compression members so proportioned and supported that they will not fail by instability before the compressive yield strength is reached. In the case of tension members, only a part of the increase in yield strength can be utilized under present design requirements because these requirements specify a definite ratio of allowable yield stress to ultimate stress, and the ultimate strength of the artificially aged material is not increased in the same proportion as is the yield strength.

The increase in yield strength is accompanied by a change in the elongation in 2 inches from about 18 percent to about 6 percent. This decrease in elongation will undoubtedly add to the difficulty of

forming the material during fabrication. In many cases, however, the added difficulty can be avoided by completing the forming operations prior to artificial aging.

Figure 2 also shows that for any aging time the temperature must be maintained within a range of ±5°F of the optimum value in order that the best increase of yield strength may be obtained. This standard of temperature maintenance is readily attainable with modern heat-treating equipment.

The variation in yield strength of alclad 24S-T material that is subjected to artificial aging at constant temperatures for varying periods of time is shown in figure 3. It will be noted on this figure that for values of temperature above 350° F there is an aging time which will result in a maximum increase of yield strength. For aging times less than or greater than the optimum time, lower values of yield stress will be obtained. At temperatures in excess of 425° F, the aging time becomes very critical. The danger of underaging or overaging of the material with consequent large decrease of yield strength is quite serious. For this reason, aging temperatures in excess of 425° F are not feasible for production where the character of the work is changing and where it is difficult to determine the exact time at which the material reaches the aging temperature. At aging temperatures of 400° F and lower, two important advantages exist; namely, higher absolute values of yield strength can be obtained and there is a considerable range of time at which aging may be terminated without appreciable loss of yield strength by reason of small amounts of underaging or overaging.

Figure 4 presents a curve of yield-strength maximums for various combinations of time and temperature. Within the range of values covered by this investigation, this curve shows that, as aging temperature decreases, the aging time required for best yield strength increases. The curve also shows that the higher values of yield strength are obtained at the combinations of lower temperatures and longer aging times shown on this figure.

Figure 5 shows the variation of the tensile properties of 24S-T with temperature for a constant aging time of 2 hours. When figure 5 is compared with figure 2, it is evident that 24S-T material responds to artificial aging in a manner similar to alclad 24S-T.

The test specimens which were aged for 6 hours at various temperatures are shown after fracture in figure 6. The change in elongation is clearly seen in the final lengths of the specimens. The characteristic fractures that occurred at the various temperatures for each aging time are also shown. At temperatures below the range of critical aging temperatures, as in the 100° F and 200° F specimens on figure 6, the

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fracture was normal to the direction of the load but was inclined at 45° to the thickness of the material. In and beyond the region of temperatures corresponding to the greatest decrease of elongation, temperatures of 370° F and higher, the fracture changed to one that was inclined at 30° to the width of the specimen. The surface of the fracture was relatively smooth for the material aged below the critical temperatures but it became very rough and irregular in the specimens aged at the higher temperatures. In the transition range of temperatures, the fracture was partly of both types as shown by the specimens marked 300° F and 350° F in figure 6.

STRESS-STRAIN CURVES

The tensile stress-strain curves for the specimens tested are shown in figures 7 to 12. The 0.2-percent-offset yield strength is indicated on each stress-strain curve by a short intercept line. These yield strengths were used in preparing figures 2 to 5. The stress-strain curves show that the modulus of elasticity is substantially the same for the combinations of temperature and time included in this investigation. It can be observed, however, that as the aging temperature increases the initial part of the stress-strain curve tends to develop more curvature, which indicates a trend toward reduction of the proportional limit at the higher aging temperatures.

CONCLUSIONS

Artificial aging of alclad 24S-T aluminum-alloy sheet material in the as-received condition produces a substantial increase in yield strength, a small increase in ultimate strength, and a large decrease in elongation.

The artificial-aging process produces essentially the same effect on 24S-T sheet material as on alclad 24S-T sheet material.

At any given temperature there is an optimum value of aging time required to obtain maximum value of yield strength. In general, the aging time required to achieve maximum yield strength becomes less as the temperature increases.

The range of aging temperatures for which a substantial increase in the yield strength is noted is small.

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National Advisory Committee for Aeronautics,
Langley Field, Va.

REFERENCE

1. Mozley, Paul P.: Elevated Temperature Aging of 24S Aluminum Alloy. Paper presented at the eleventh annual meeting of the Inst. Aero. Sci., Jan. 1943.

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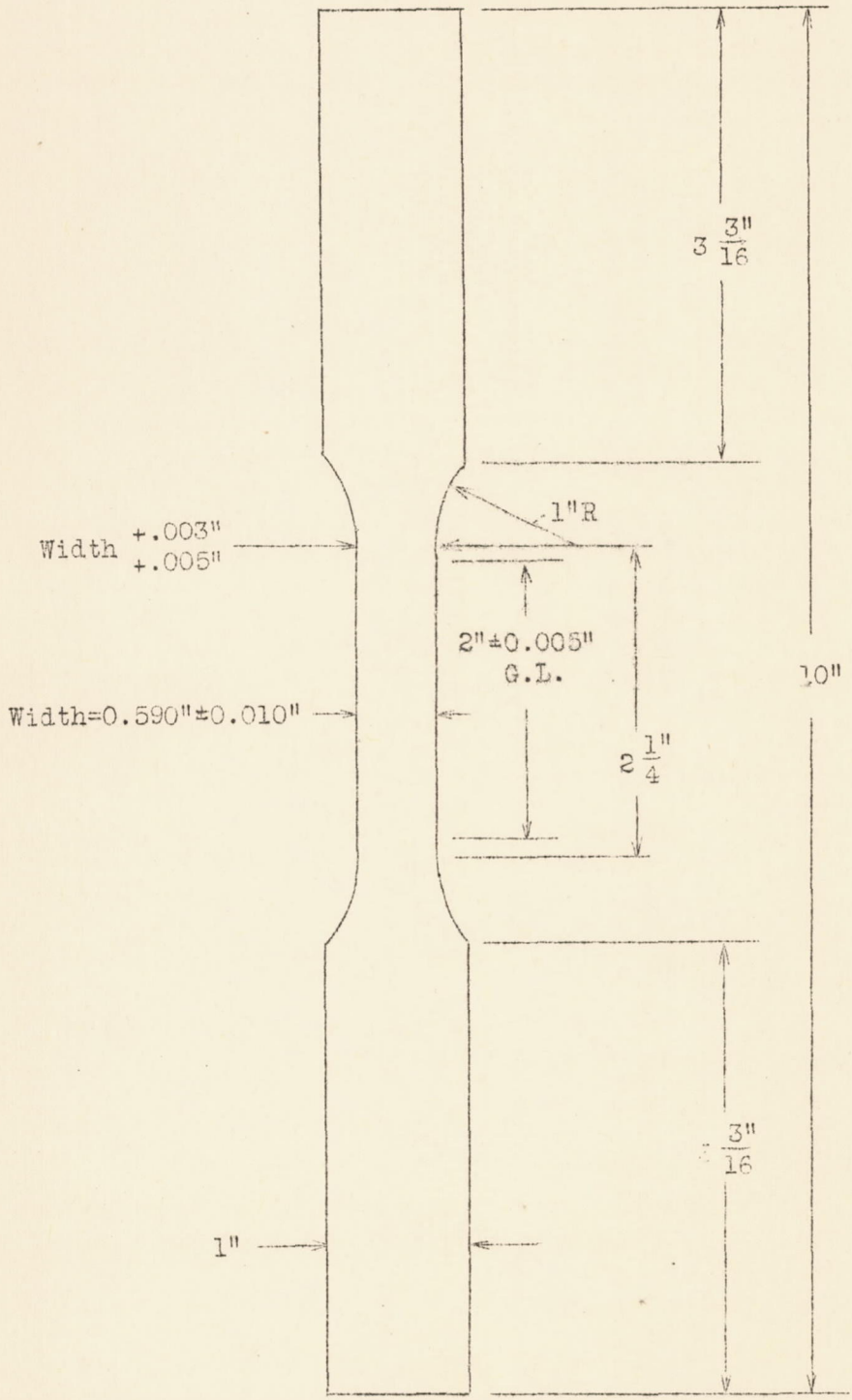

Figure 1.- Tensile test specimen.

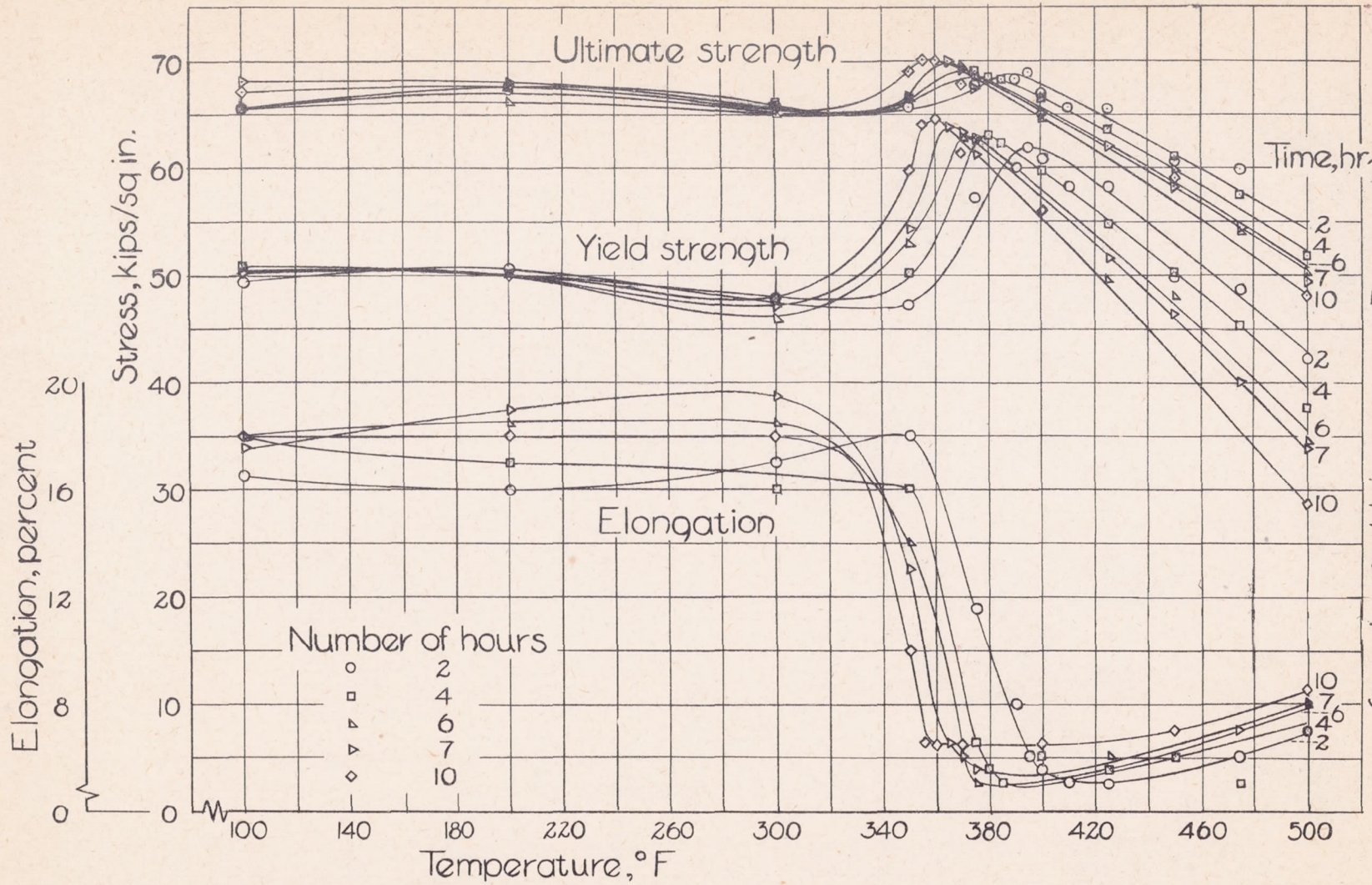

Figure 2.- Tensile properties of alclad 24S-T aluminum alloy aged for constant periods of time at various temperatures.

Fig. 2

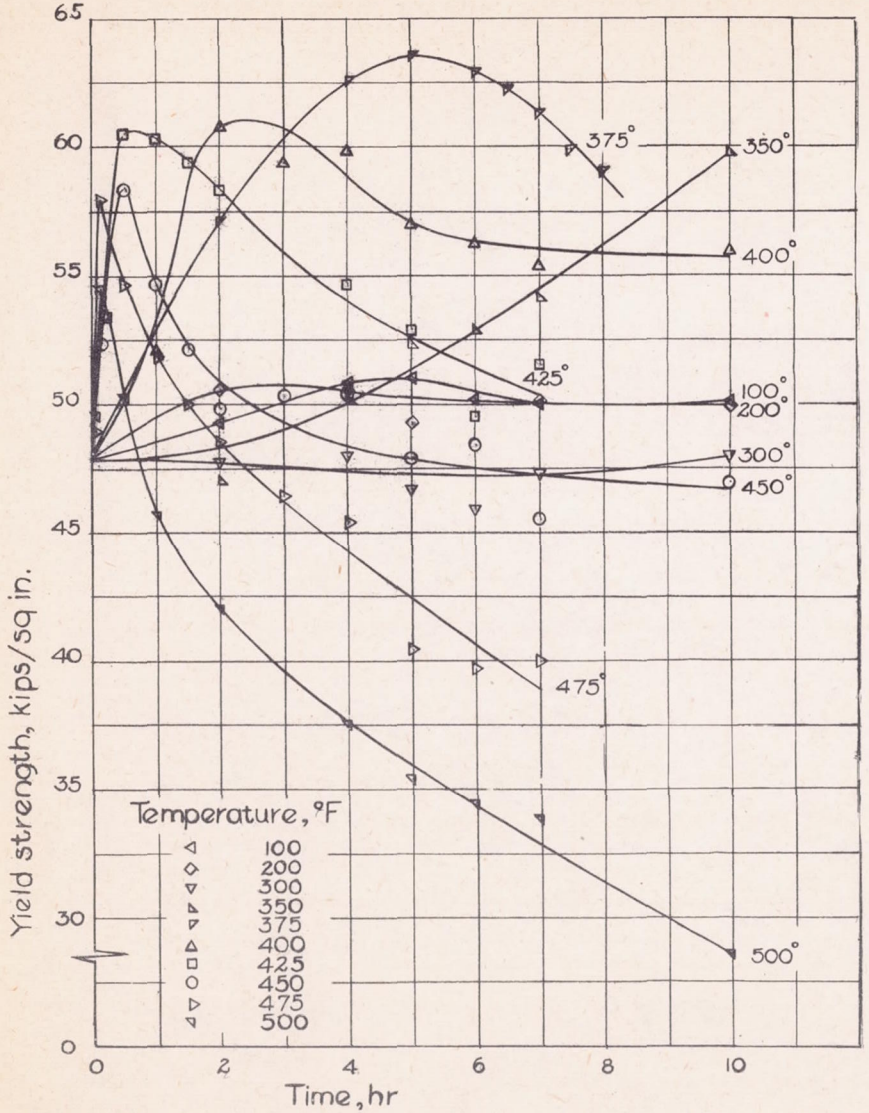

Figure 3.-Tensile yield strength for alclad 24S-T aluminum alloy aged at constant temperatures and various times.

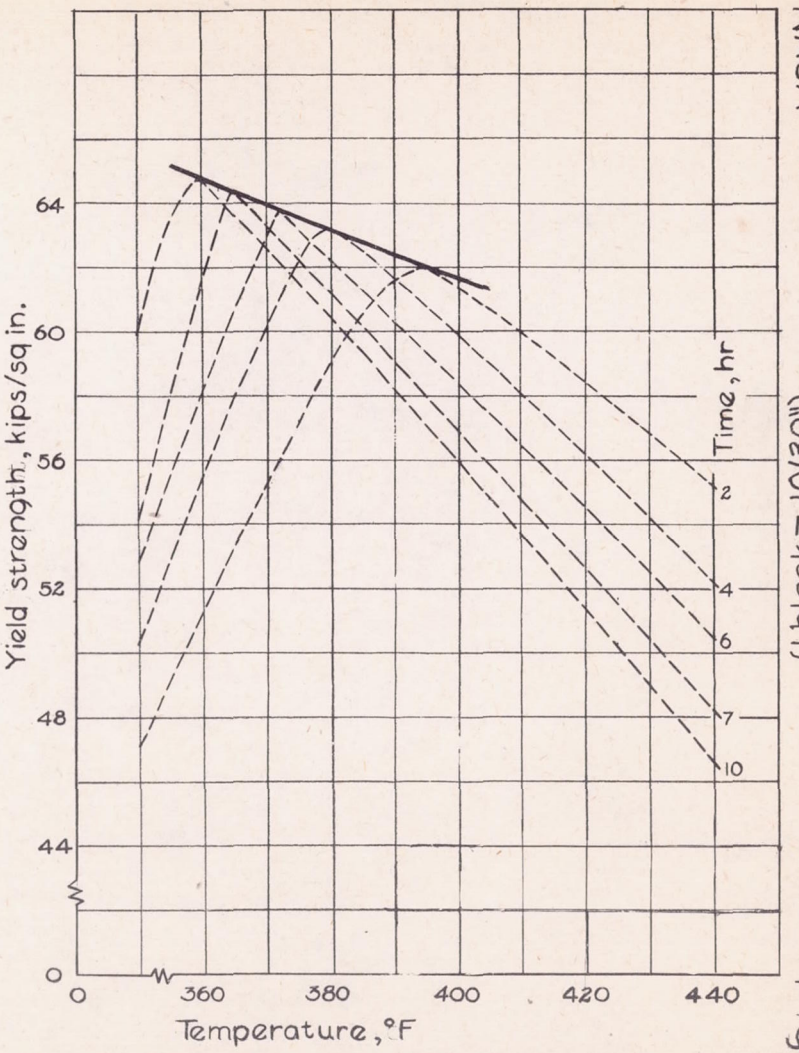

Figure 4.-Critical values of time and temperature for maximum yield strength.

NACA (1 block = 10/30")

Figs. 3, 4

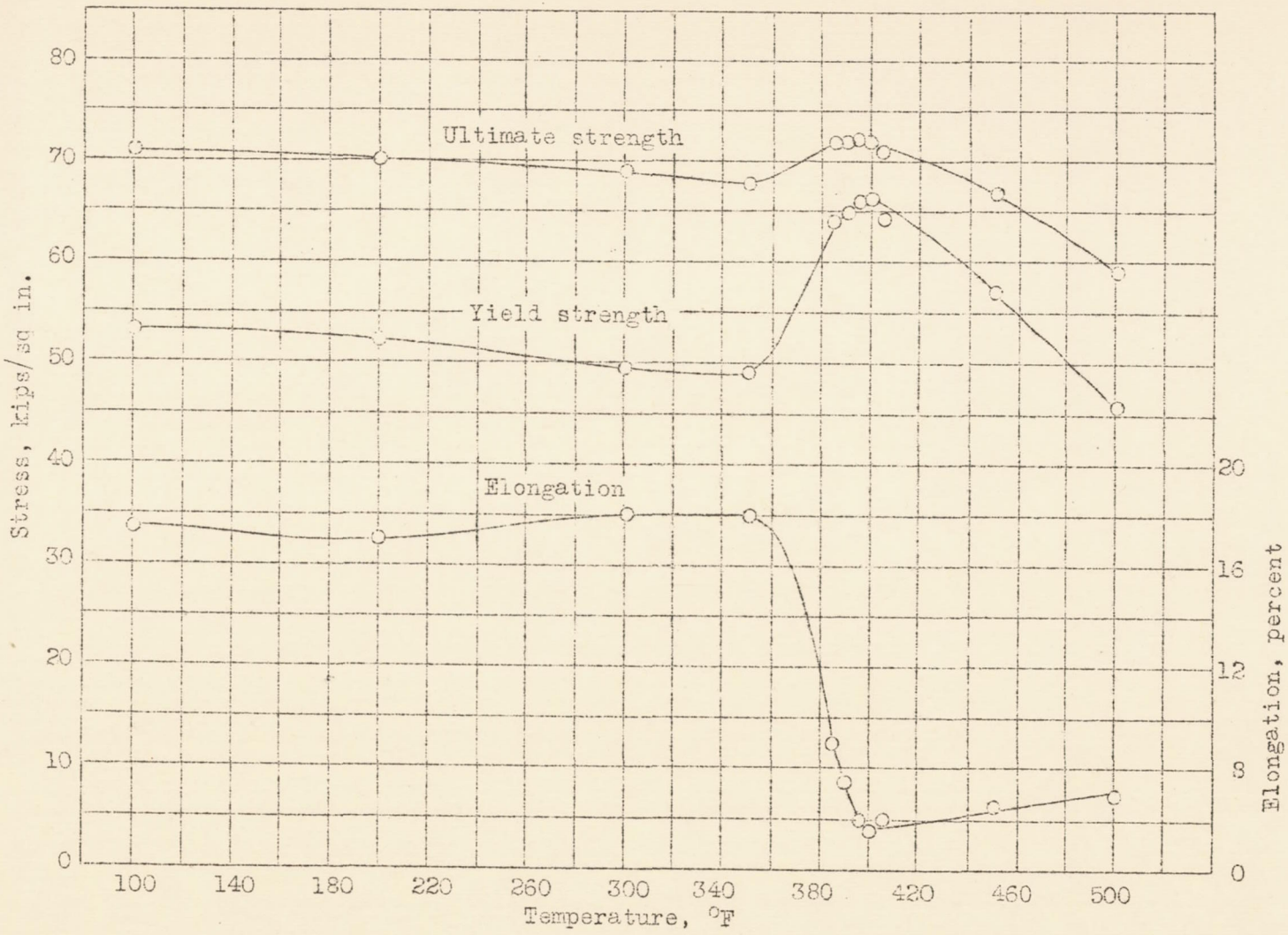

Figure 5.- Tensile properties of 24S-T aluminum alloy aged for two hours at various temperatures.

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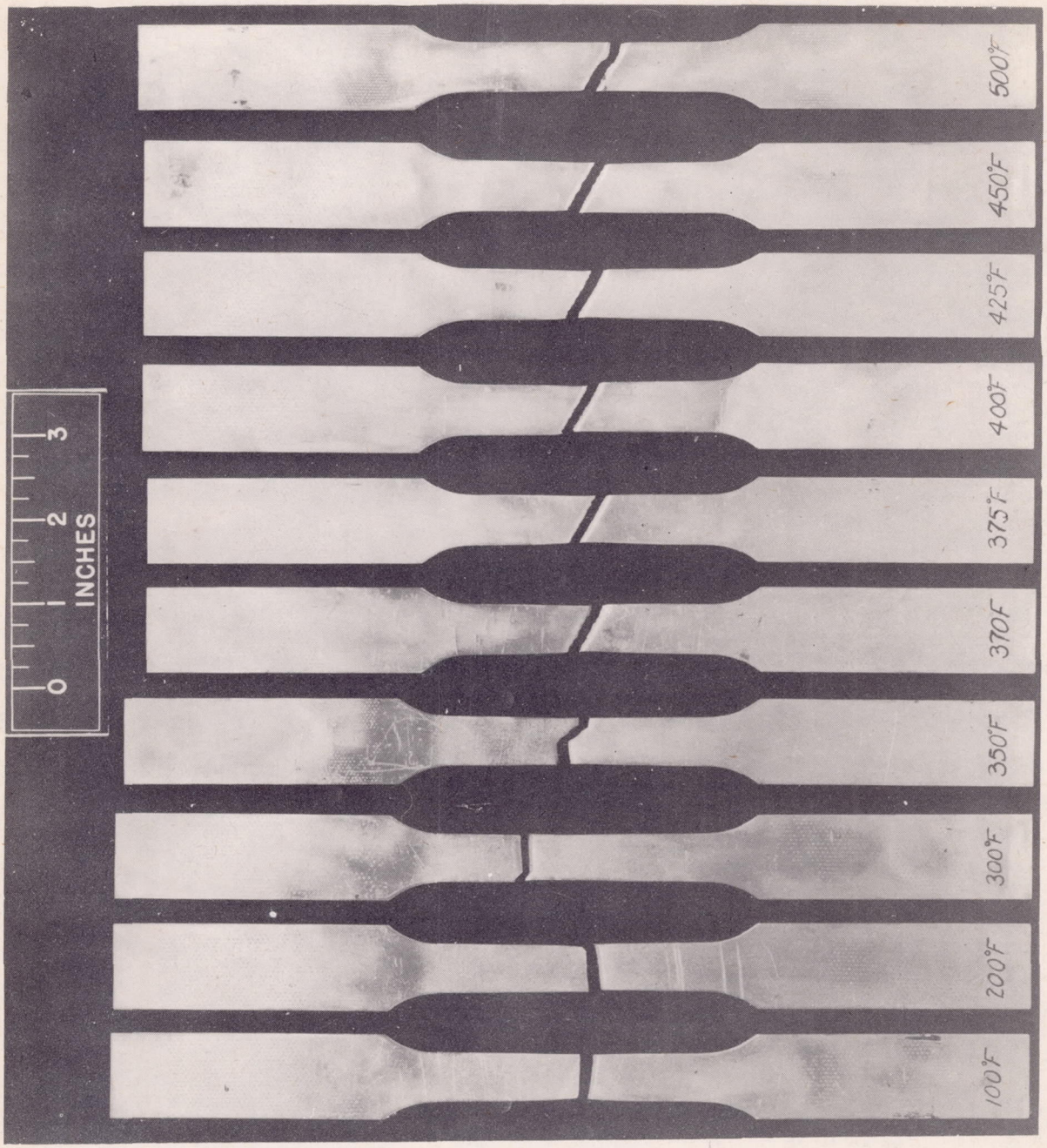

Figure 6.- Artificially aged test specimens after fracture. Aging time 6 hours.

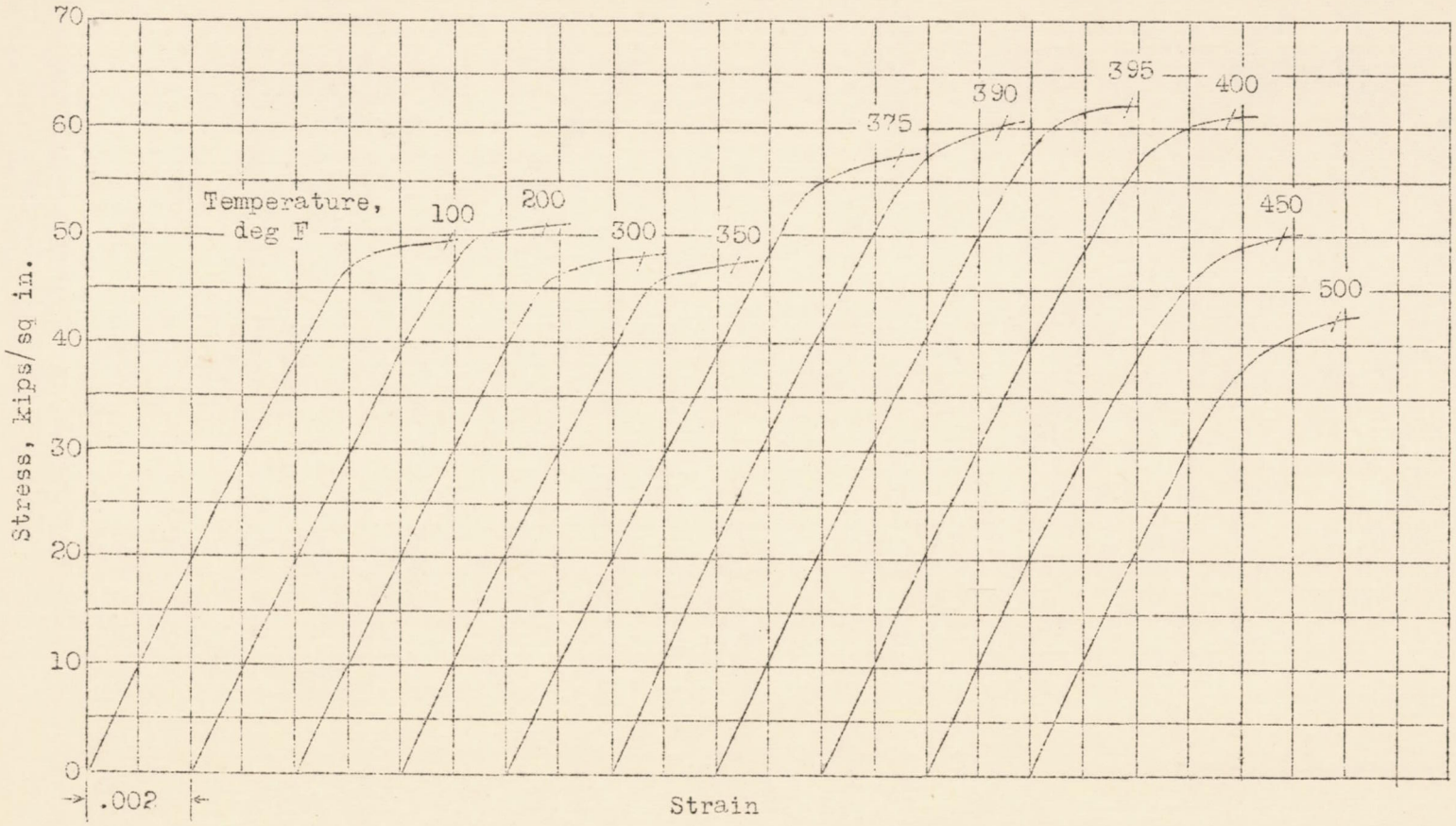

Figure 7.- Stress-strain curves for alclad 24S-T aluminum alloy aged for two hours at various temperatures.

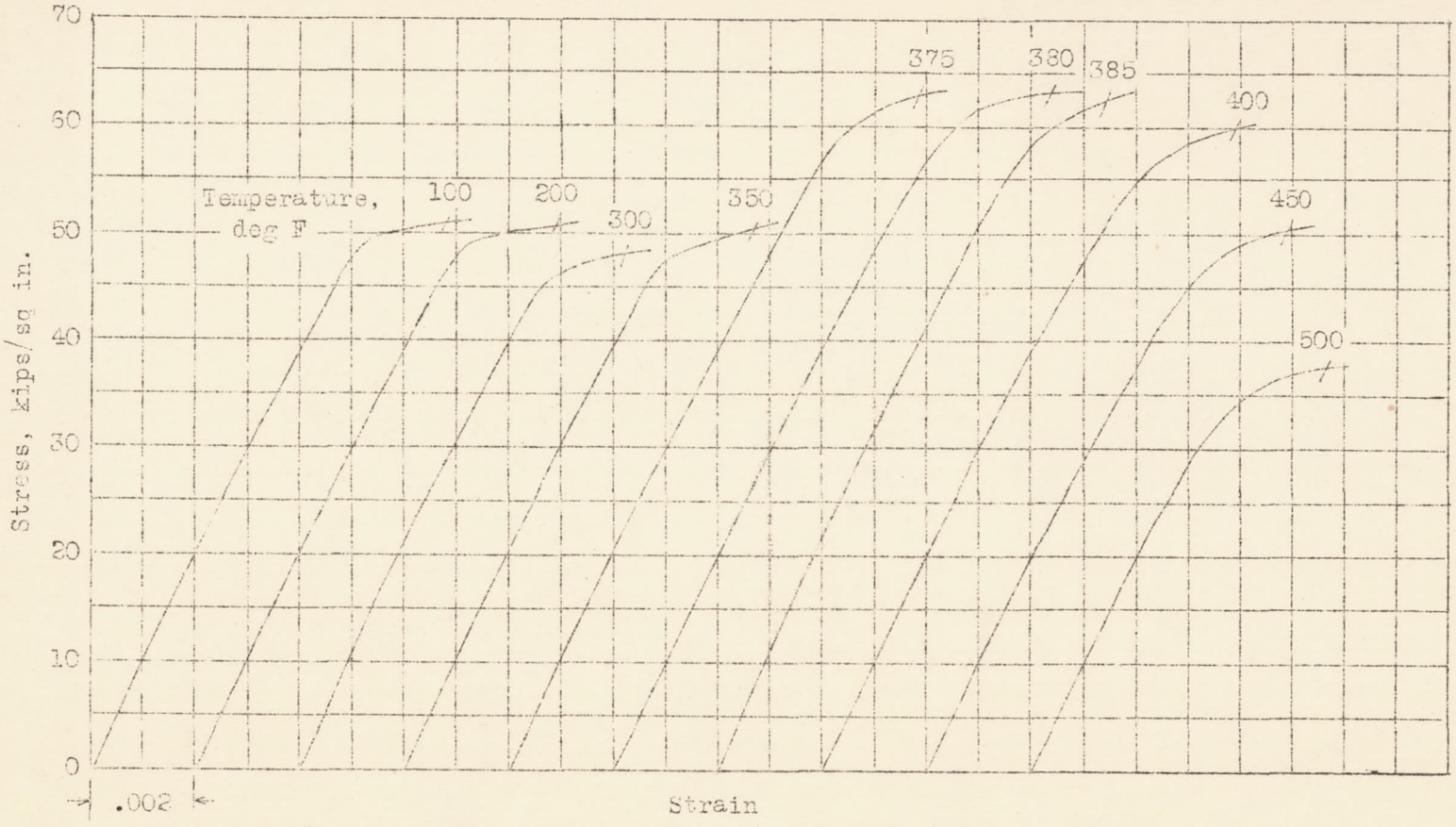

Figure 8.- Stress-strain curves for alclad 24S-T aluminum alloy aged for four hours at various temperatures.

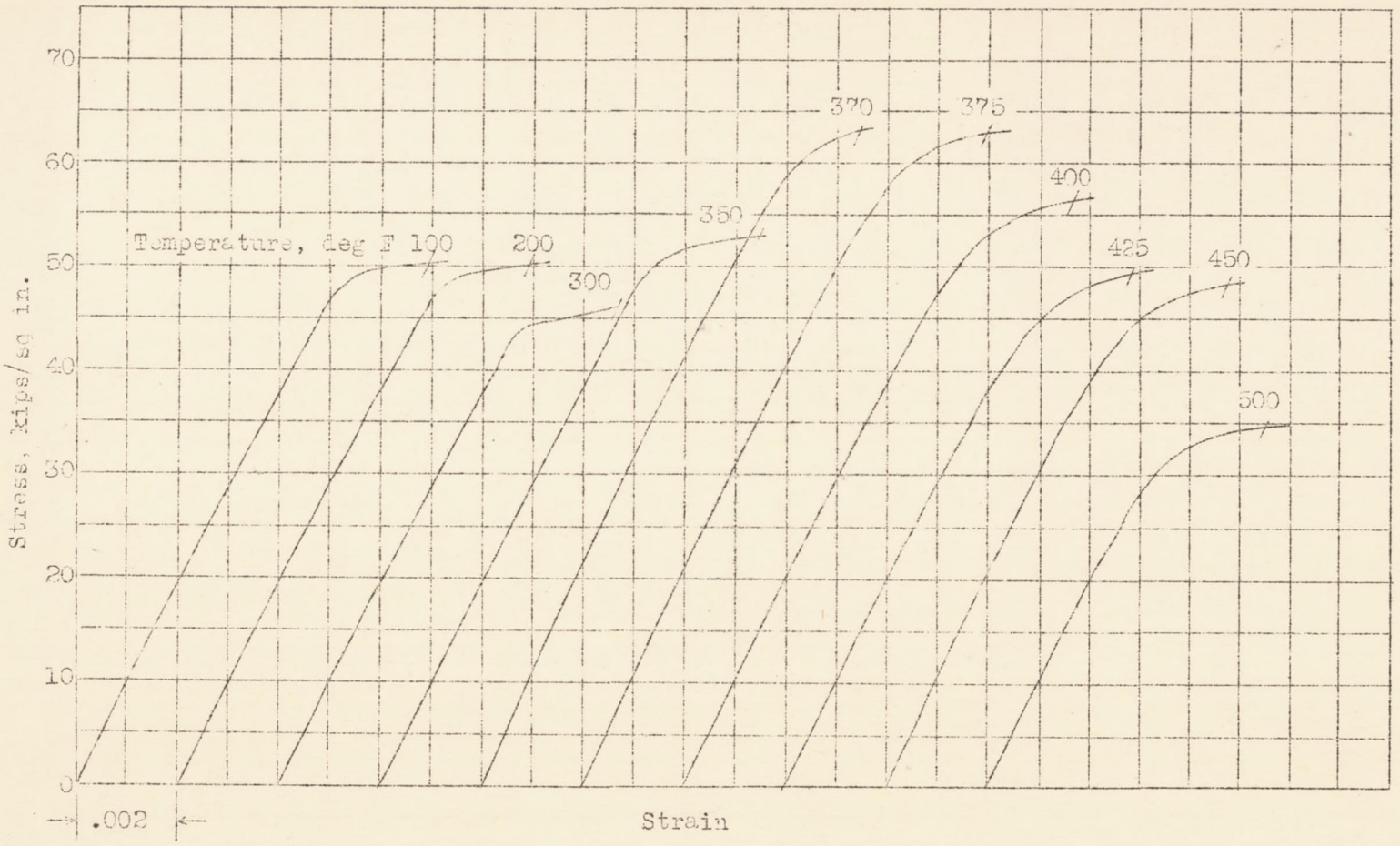

Figure 9.- Stress-strain curves for alclad 24S-T aluminum alloy aged for six hours at various temperatures.

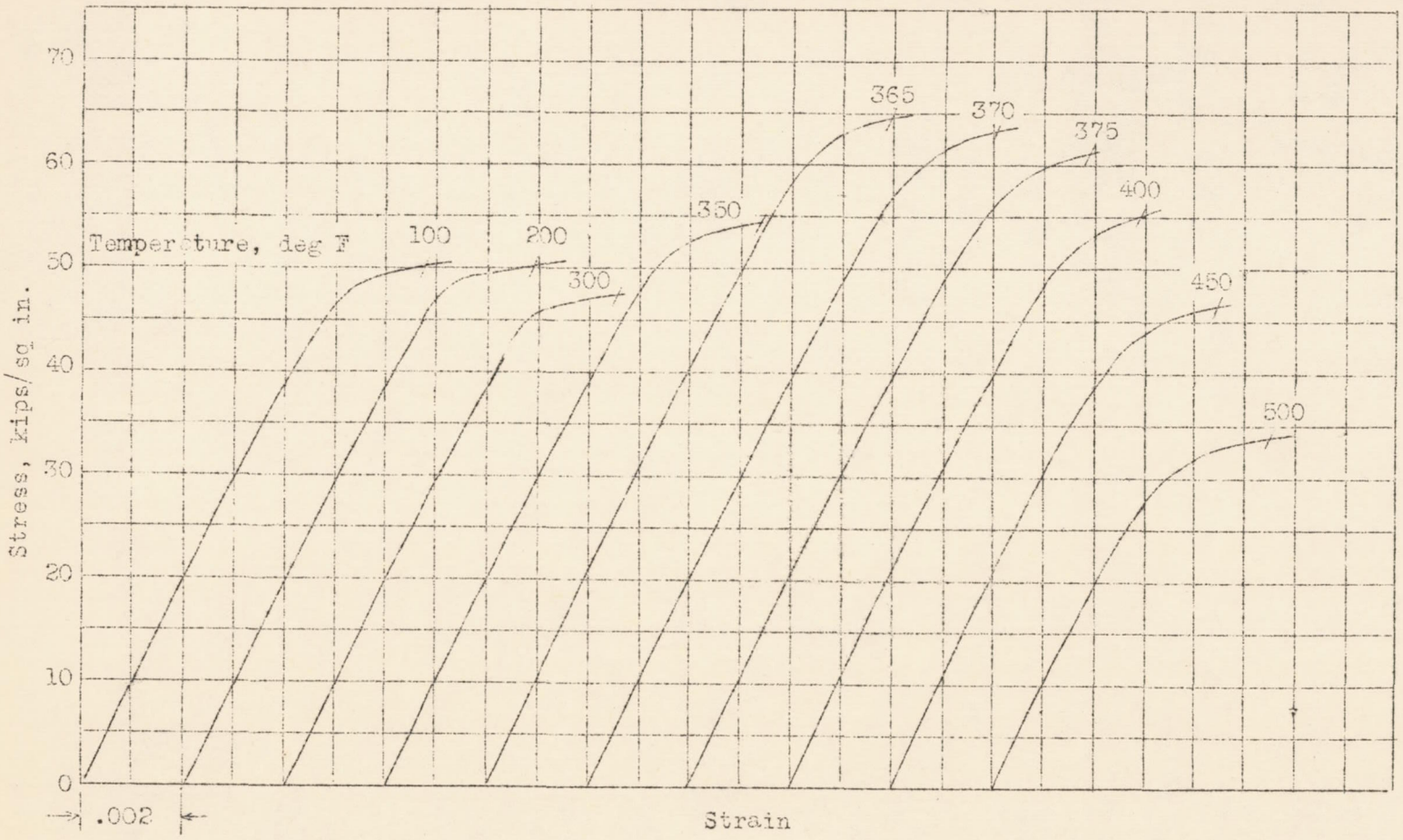

Figure 10.- Stress-strain curves for alclad 24S-T aluminum alloy aged for seven hours at various temperatures.

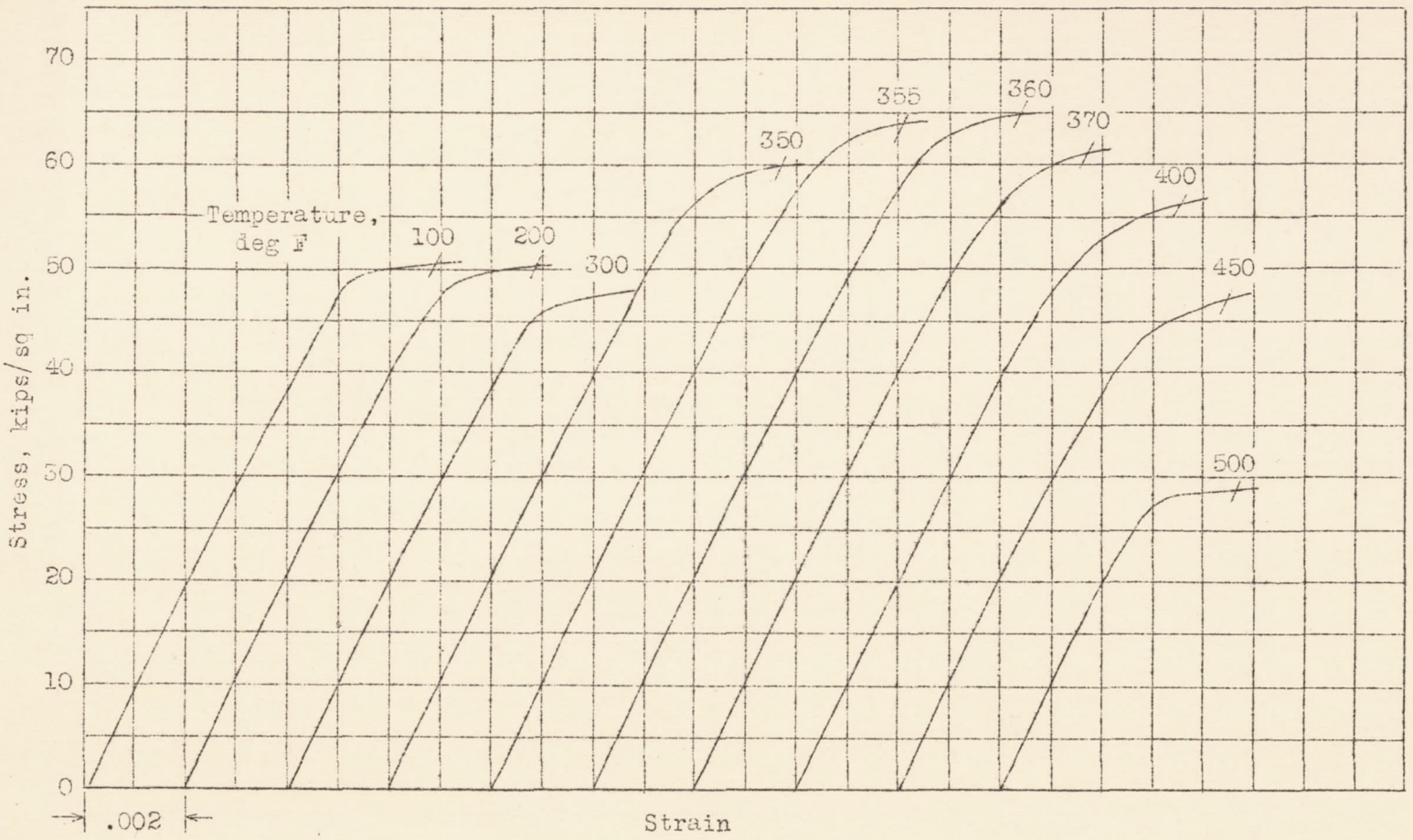

Figure 11.- Stress-strain curves for alclad 24S-T aluminum alloy aged for ten hours at various temperatures.

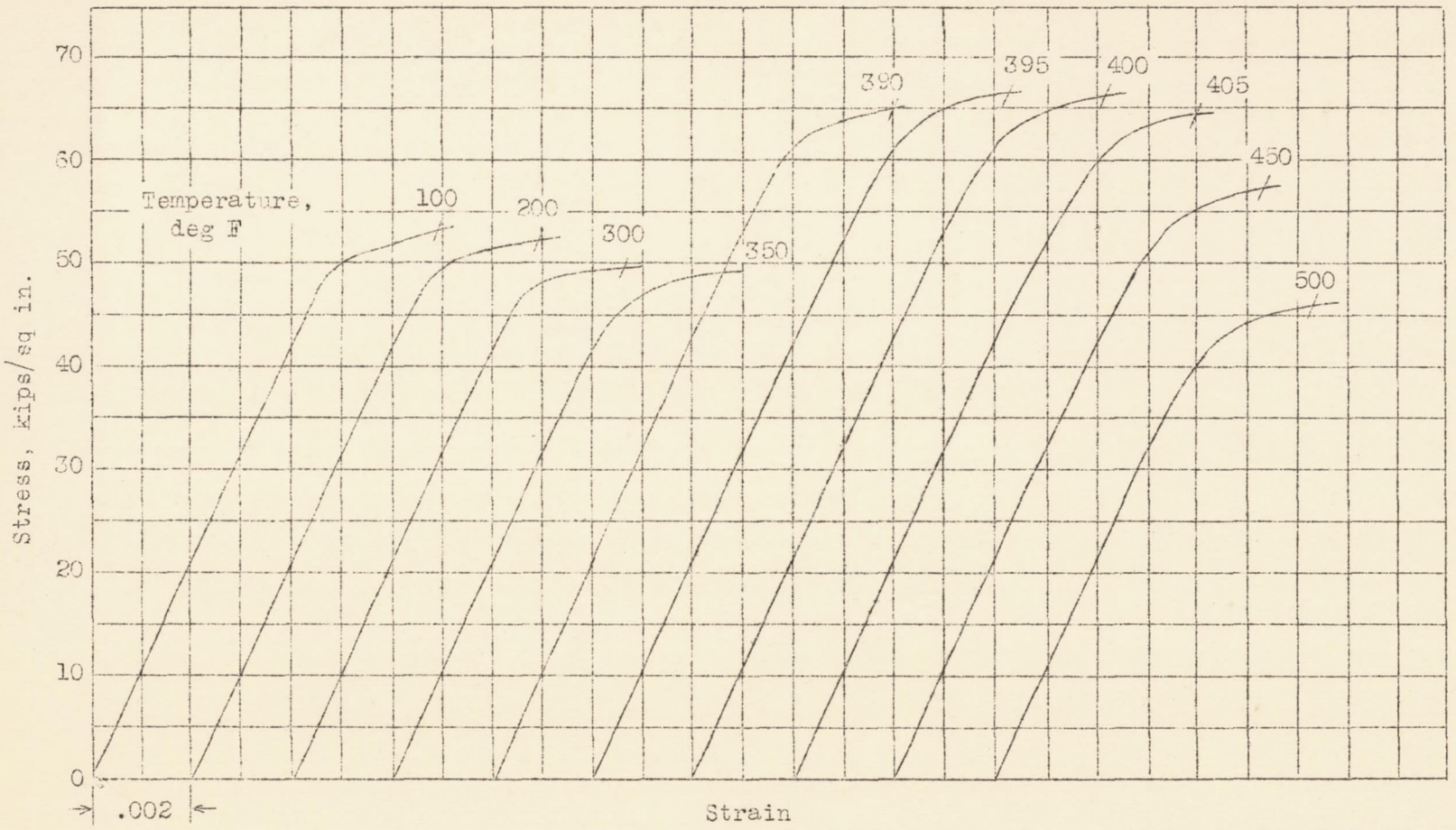

Figure 12.- Stress-strain curves for 24S-T aluminum alloy aged for two hours at various temperatures.